

US010742924B2

(12) **United States Patent**
Bodinet

(10) **Patent No.:** **US 10,742,924 B2**
(45) **Date of Patent:** ***Aug. 11, 2020**

(54) **SYSTEMS AND METHODS FOR
BIDIRECTIONAL SPEED RAMPING**

(71) Applicant: **GoPro, Inc.**, San Mateo, CA (US)
(72) Inventor: **Joshua Bodinet**, San Diego, CA (US)
(73) Assignee: **GoPro, Inc.**, San Mateo, CA (US)

(*) Notice: Subject to any disclaimer, the term of this
 patent is extended or adjusted under 35
 U.S.C. 154(b) by 0 days.

 This patent is subject to a terminal dis-
 claimer.

(21) Appl. No.: **15/972,600**
(22) Filed: **May 7, 2018**

(65) **Prior Publication Data**

 US 2018/0255268 A1 Sep. 6, 2018

Related U.S. Application Data

(63) Continuation of application No. 15/183,667, filed on
 Jun. 15, 2016, now Pat. No. 9,967,515.

(51) **Int. Cl.**
 H04N 5/783 (2006.01)
 H04N 5/91 (2006.01)
 G11B 27/00 (2006.01)
 G11B 27/19 (2006.01)

(52) **U.S. Cl.**
 CPC **H04N 5/783** (2013.01); **G11B 27/005**
 (2013.01); **G11B 27/19** (2013.01); **H04N 5/91**
 (2013.01)

(58) **Field of Classification Search**
 CPC H04N 5/783; G11B 27/005
 See application file for complete search history.

(56) **References Cited**

 U.S. PATENT DOCUMENTS

6,633,685 B1 10/2003 Kusama
7,512,886 B1 3/2009 Herberger
7,885,426 B2 2/2011 Golovchinsky
7,970,240 B1 6/2011 Chao
 (Continued)

 FOREIGN PATENT DOCUMENTS

JP H09181966 A 7/1997
JP 2005252459 A 9/2005
 (Continued)

 OTHER PUBLICATIONS

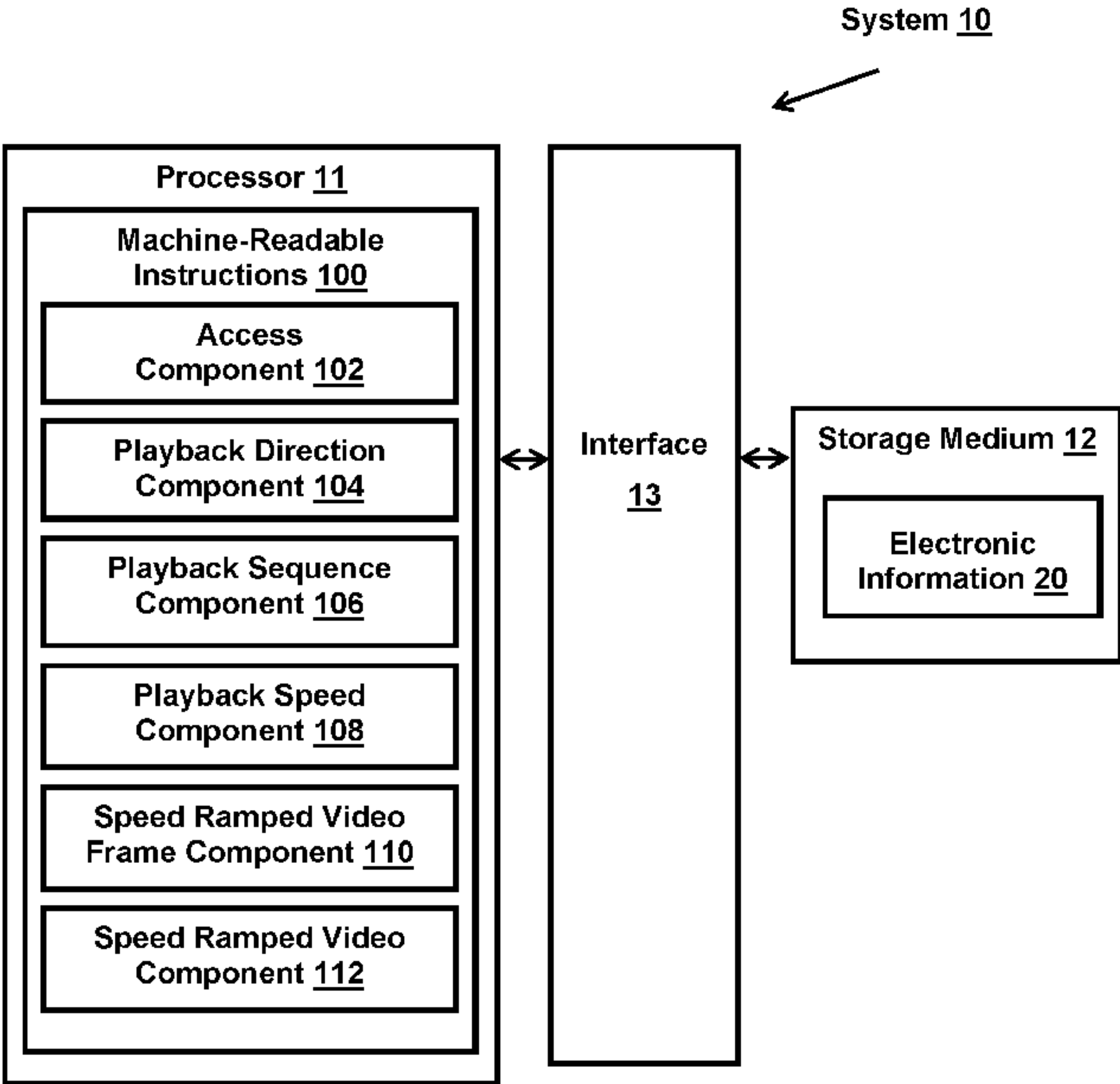
PCT International Written Opinion for PCT/US2015/041624, dated
Dec. 17, 2015, 7 Pages.
 (Continued)

 Primary Examiner — Girumsew Wendmagegn
(74) Attorney, Agent, or Firm — Esplin & Associates, PC

(57) **ABSTRACT**

Electronic information defining visual content within video
frames may be accessed. Video frames may be ordered in a
source sequence. Positions in the source sequence may be
associated with playback directions. Video frames may be
ordered in a playback sequence based on the playback
directions. The playback sequence may characterize a play-
back order in which video frames are displayed during
playback. Video frames in the playback sequence may be
associated with playback speeds. The playback speeds may
determine perceived speeds with which visual content is
displayed during playback. Speed ramped video frames may
be determined based on the playback sequence and the
playback speeds. A speed ramped video may be generated
based on the speed ramped video frames.

20 Claims, 7 Drawing Sheets



(56)

References Cited

U.S. PATENT DOCUMENTS

8,180,161	B2	5/2012	Haseyama
8,606,073	B2	12/2013	Woodman
8,774,560	B2	7/2014	Sugaya
8,971,623	B2	3/2015	Gatt
8,990,328	B1	3/2015	Grigsby
9,041,727	B2	5/2015	Ubillos
9,142,257	B2	9/2015	Woodman
9,342,376	B2	5/2016	Jain
9,418,283	B1	8/2016	Natarajan
9,967,515	B1 *	5/2018	Bodinet H04N 5/783
2002/0165721	A1	11/2002	Chang
2004/0001706	A1	1/2004	Jung
2005/0025454	A1	2/2005	Nakamura
2005/0097614	A1 *	5/2005	Pedlow, Jr. H04N 7/17318 725/90
2005/0108031	A1	5/2005	Grosvenor
2005/0198018	A1	9/2005	Shibata
2006/0080286	A1	4/2006	Svensen
2006/0115108	A1	6/2006	Rodriguez
2008/0123976	A1	5/2008	Coombs
2008/0183843	A1	7/2008	Gavin
2009/0019995	A1	1/2009	Miyajima
2009/0027499	A1	1/2009	Nicholl
2009/0125559	A1	5/2009	Yoshino
2009/0252474	A1	10/2009	Nashida
2010/0046842	A1	2/2010	Conwell
2010/0086216	A1	4/2010	Lee
2010/0161720	A1	6/2010	Colligan
2010/0199182	A1	8/2010	Lanza
2010/0274714	A1	10/2010	Sims
2010/0318660	A1	12/2010	Balsubramanian
2011/0103700	A1	5/2011	Haseyama
2011/0137156	A1	6/2011	Razzaque
2011/0170086	A1	7/2011	Oouchida
2011/0206351	A1	8/2011	Givoly
2011/0242098	A1	10/2011	Tamaru
2012/0014673	A1	1/2012	O'Dwyer
2012/0027381	A1	2/2012	Kataoka
2012/0030263	A1	2/2012	John
2012/0141019	A1	6/2012	Zhang
2012/0210205	A1	8/2012	Sherwood
2012/0210228	A1	8/2012	Wang
2012/0246114	A1	9/2012	Edmiston
2012/0283574	A1	11/2012	Park
2013/0182166	A1	7/2013	Shimokawa
2013/0235071	A1	9/2013	Ubillos
2013/0239051	A1	9/2013	Albouze
2013/0330019	A1	12/2013	Kim
2014/0149865	A1	5/2014	Tanaka
2014/0152762	A1	6/2014	Ukil
2014/0282661	A1	9/2014	Martin
2015/0039646	A1	2/2015	Sharifi
2015/0071547	A1	3/2015	Keating
2015/0113009	A1	4/2015	Zhou
2015/0156247	A1	6/2015	Hensel
2015/0287435	A1	10/2015	Land
2016/0029105	A1	1/2016	Newman
2016/0094601	A1	3/2016	Besehanic
2016/0103830	A1	4/2016	Cheong
2016/0189752	A1	6/2016	Galant
2016/0260000	A1	9/2016	Yamakawa
2016/0286235	A1	9/2016	Yamamoto

FOREIGN PATENT DOCUMENTS

JP	2006053694	A	2/2006
JP	2008059121	A	3/2008
JP	2009053748	A	3/2009
JP	2009040538	A1	4/2009
JP	2011188004	A	9/2011
WO	2006001361	A1	1/2006
WO	2012057623	A1	5/2012
WO	2012086120	A1	6/2012

OTHER PUBLICATIONS

PCT International Search Report and Written Opinion for PCT/US15/12086 dated Mar. 17, 2016, 20 pages.

Schroff et al., 'FaceNet: A Unified Embedding for Face Recognition and Clustering,' IEEE Conference on Computer Vision and Pattern Recognition (CVPR), 2016, 10 pgs.

Parkhi et al., 'Deep Face Recognition,' Proceedings of the British Machine Vision, 2015, 12 pgs.

Iandola et al., 'SqueezeNet: AlexNet-level accuracy with 50x fewer parameters and <0.5MB model size', arXiv:1602.07360v3 [cs.CV] Apr. 6, 2016 (9 pgs.).

Ioffe et al., 'Batch Normalization: Accelerating Deep Network Training by Reducing Internal Covariate Shift,' arXiv:1502.03167, 2015, 11 pgs.

He et al., 'Deep Residual Learning for Image Recognition,' arXiv:1512.03385, 2015, 12 pgs.

Han et al., Deep Compression: Compressing Deep Neural Networks with Pruning, Trained Quantization and Huffman Coding, International Conference on Learning Representations 2016, 14 pgs.

PCT International Search Report and Written Opinion for PCT/US16/31076, dated Aug. 8, 2016, 19 Pages.

Yang et al., 'Unsupervised Extraction of Video Highlights via Robust Recurrent Auto-encoders' arXiv:1510.01442v1 [cs.CV] Oct. 6, 2015 (9 pgs).

Tran et al., 'Learning Spatiotemporal Features with 3D Convolutional Networks', arXiv:1412.0767 [cs.CV] Dec. 2, 2014 (9 pgs).

PCT International Search Report for PCT/US15/41624 dated Nov. 4, 2015, 5 pages.

PCT International Search Report for PCT/US15/23680 dated Aug. 3, 2015, 4 pages.

PSonar URL: <http://www.psonar.com/about> retrieved on Aug. 24, 2016, 3 pages.

PCT International Preliminary Report on Patentability for PCT/US2015/023680, dated Oct. 4, 2016, 10 pages.

Nicole Lee, Twitter's Periscope is the best livestreaming video app yet; Mar. 26, 2015 URL: <http://www.engadget.com/2015/03/26/periscope/> [Retrieved Aug. 25, 2015] 11 pages.

FFmpeg, "Demuxing," Doxygen, Dec. 5, 2014, 15 Pages, [online] Retrieved on Jul. 13, 2015] Retrieved from the Internet <URL: https://www.ffmpeg.org/doxygen/2.3/group_lavf_encoding.html>.

FFmpeg, "Muxing," Doxygen, Jul. 20, 2014, 9 Pages, [online] Retrieved on Jul. 13, 2015] Retrieved from the internet <URL: <https://www.ffmpeg.org/doxygen/2.3/structAVPacked.html>>.

Japanese Office Action for JP Application No. 2013-140131, dated Aug. 5, 2014, 6 pages.

Office Action for U.S. Appl. No. 13/831,124, dated Mar. 19, 2015, 14 pages.

* cited by examiner

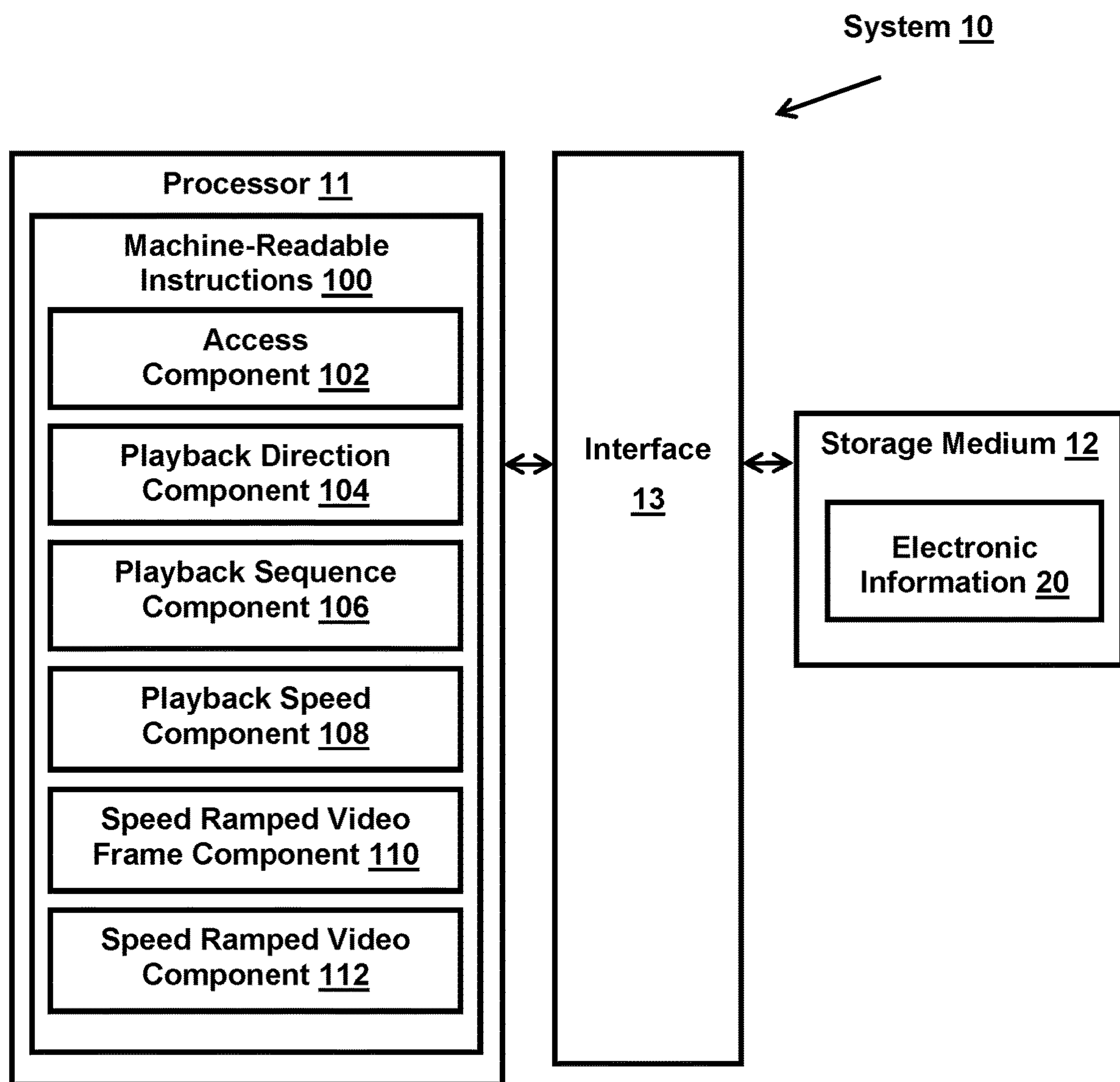


FIG. 1

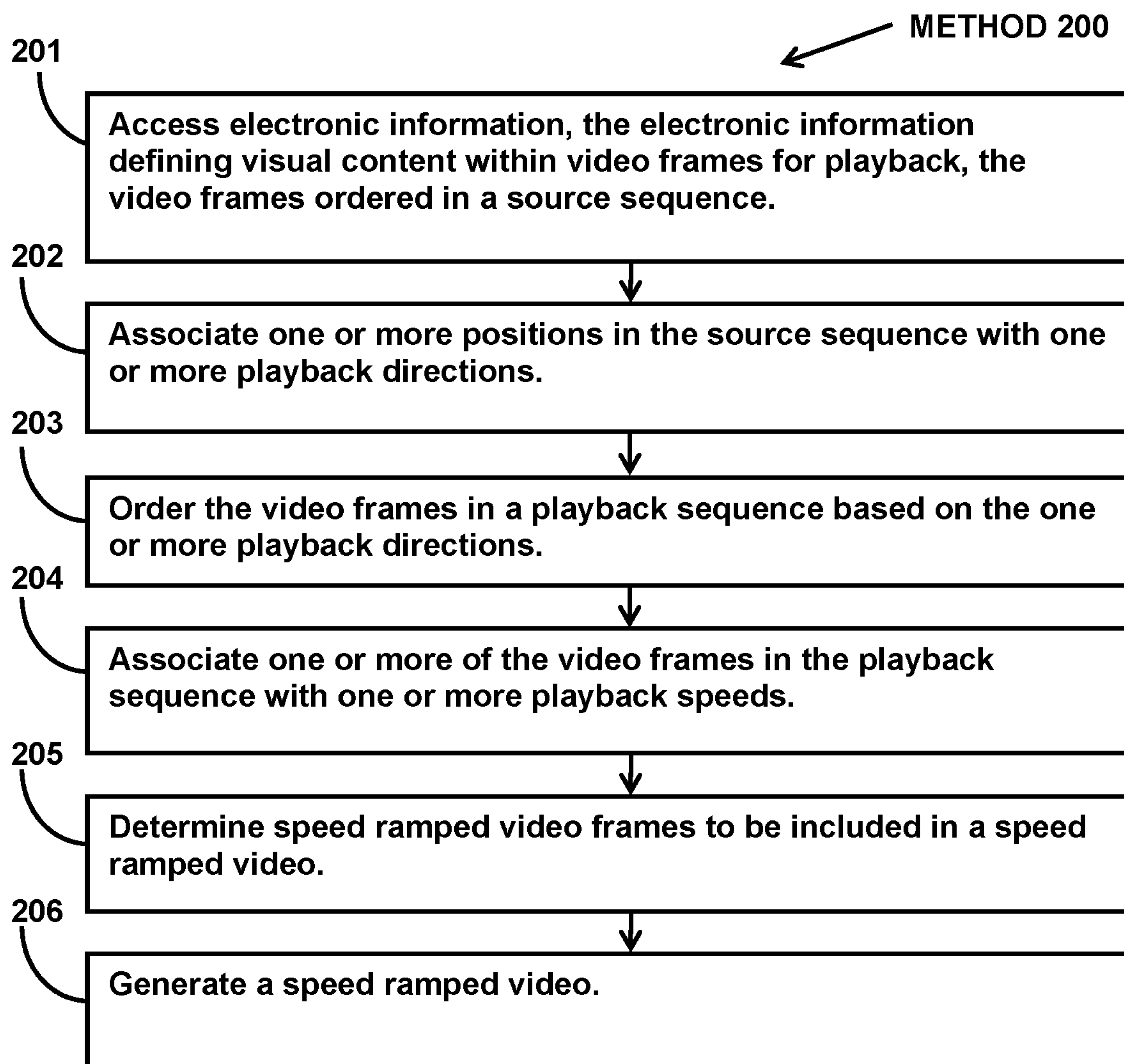


FIG. 2

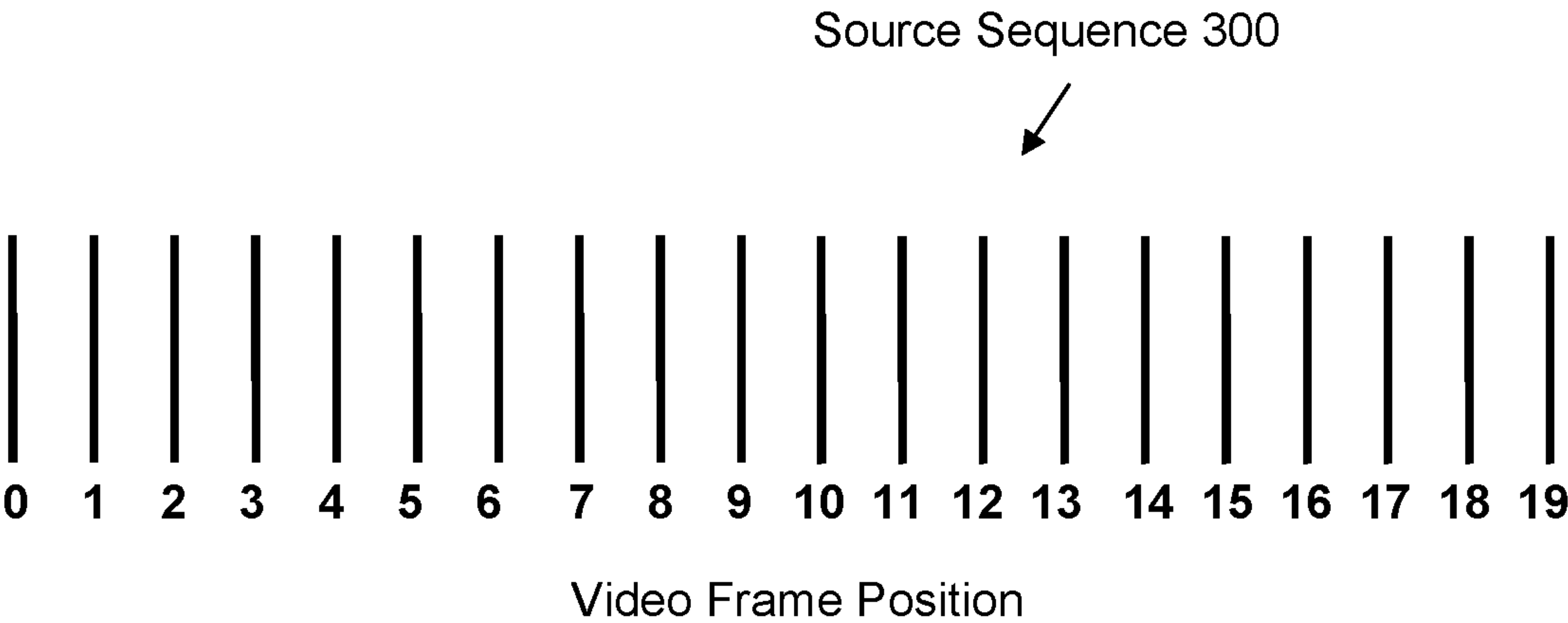


FIG. 3

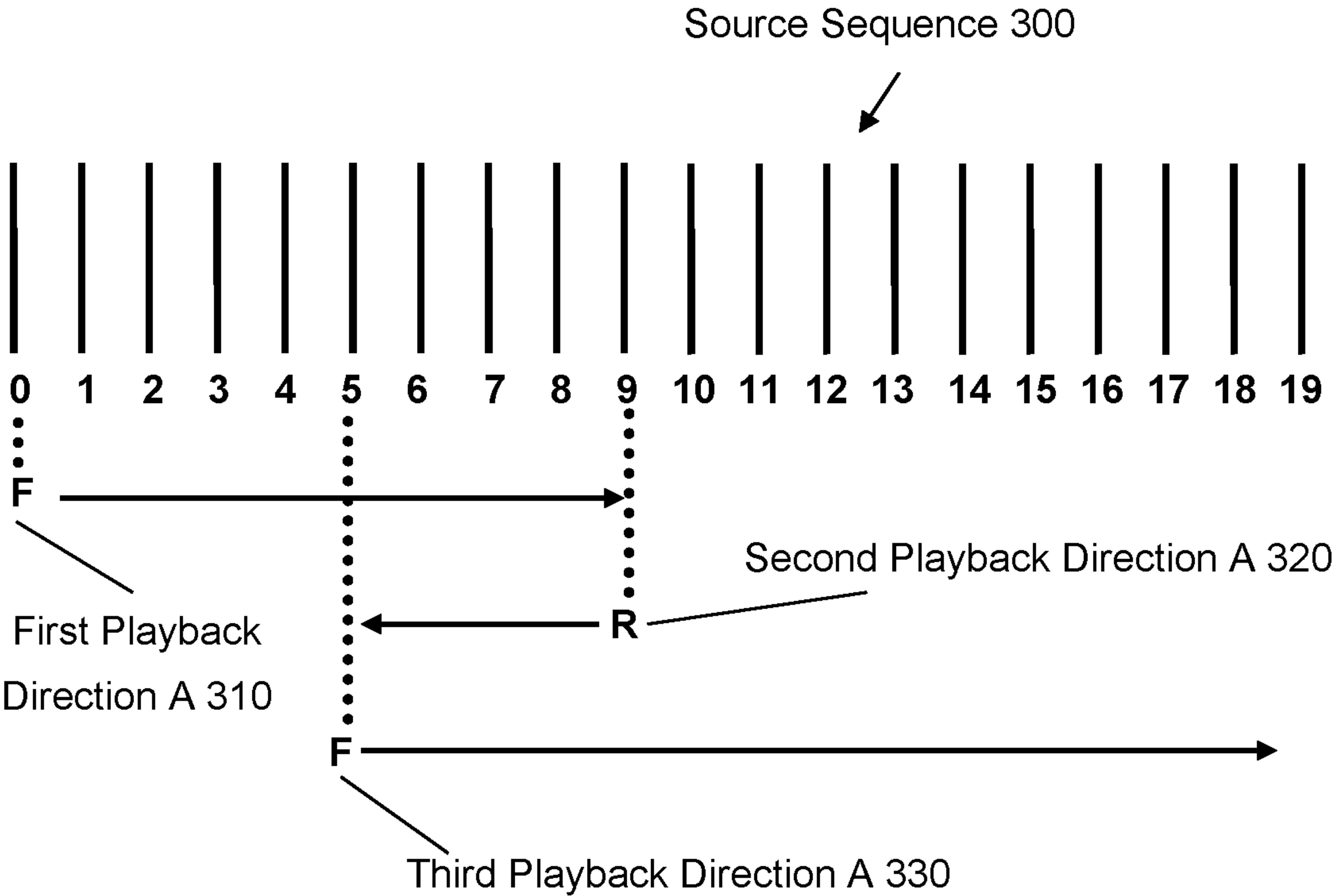


FIG. 4

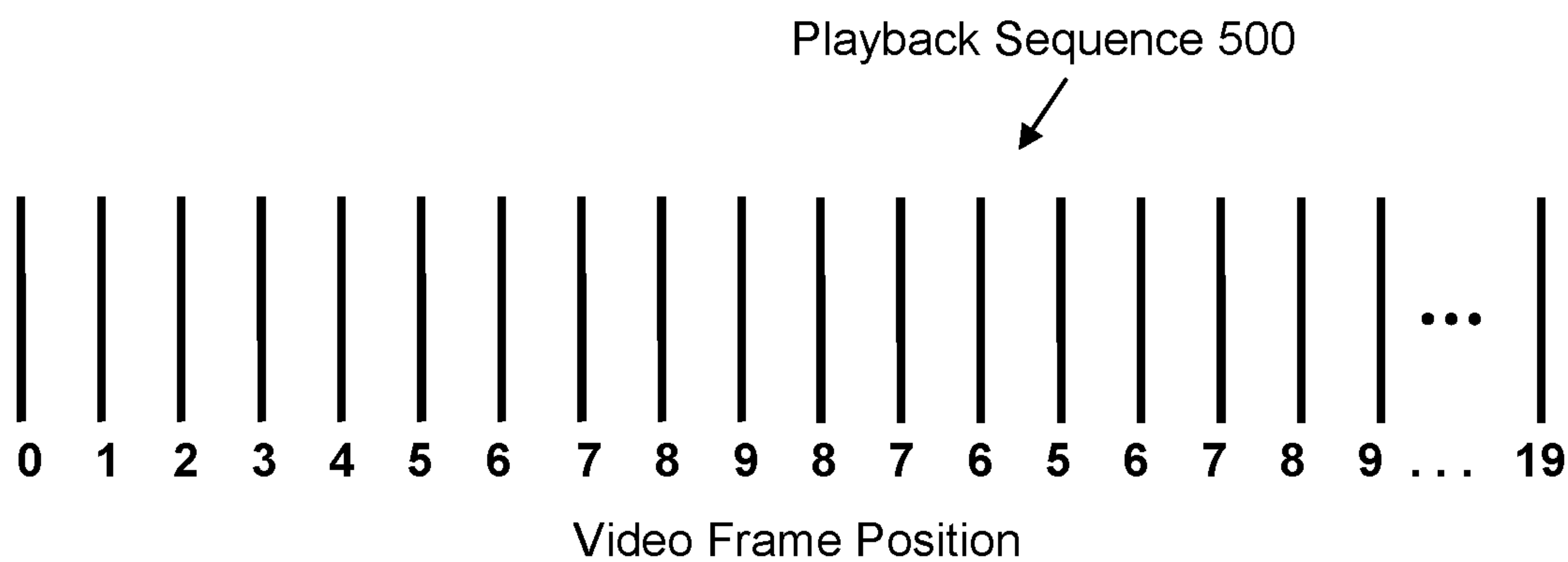


FIG. 5

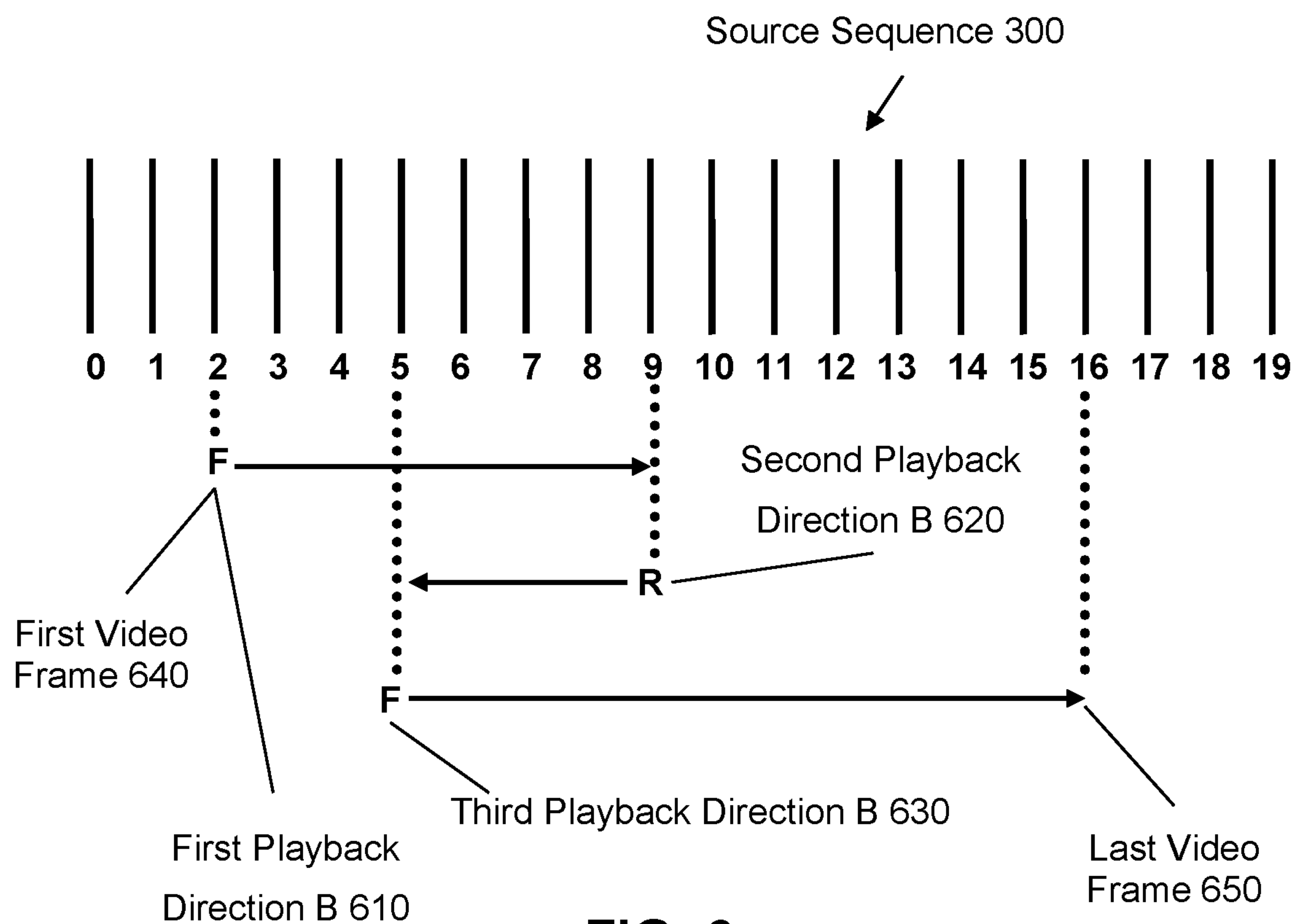


FIG. 6

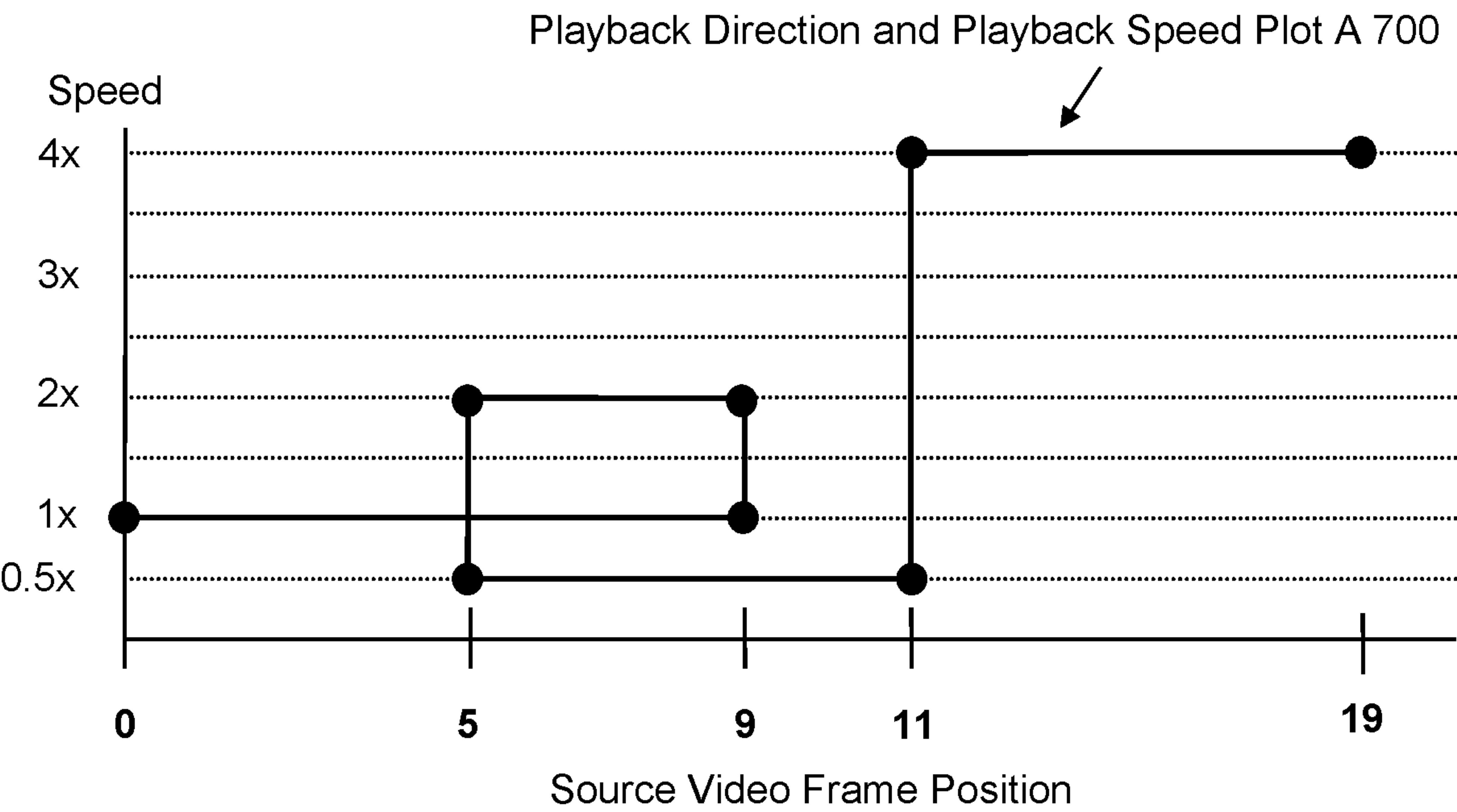


FIG. 7A

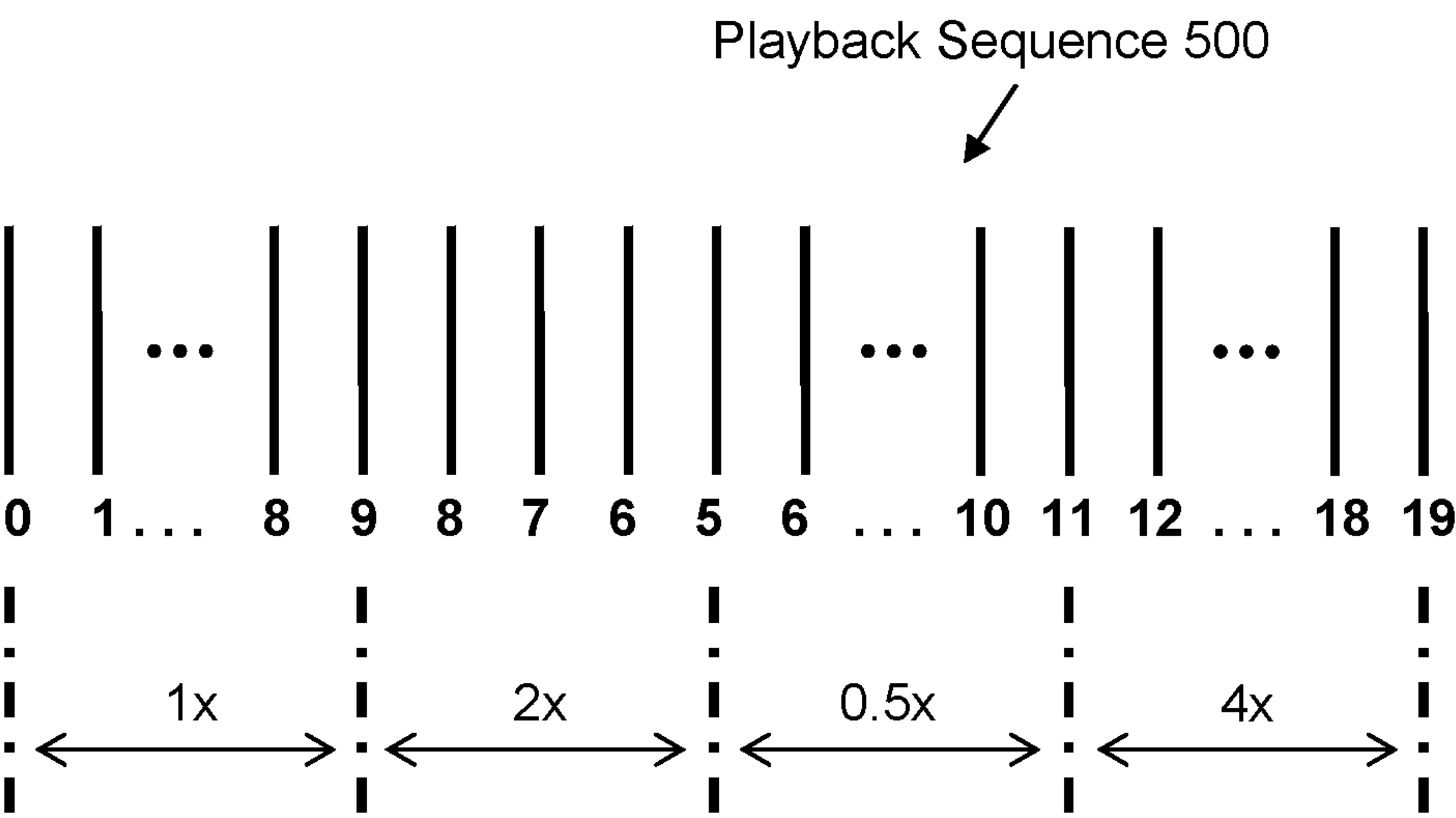


FIG. 7B

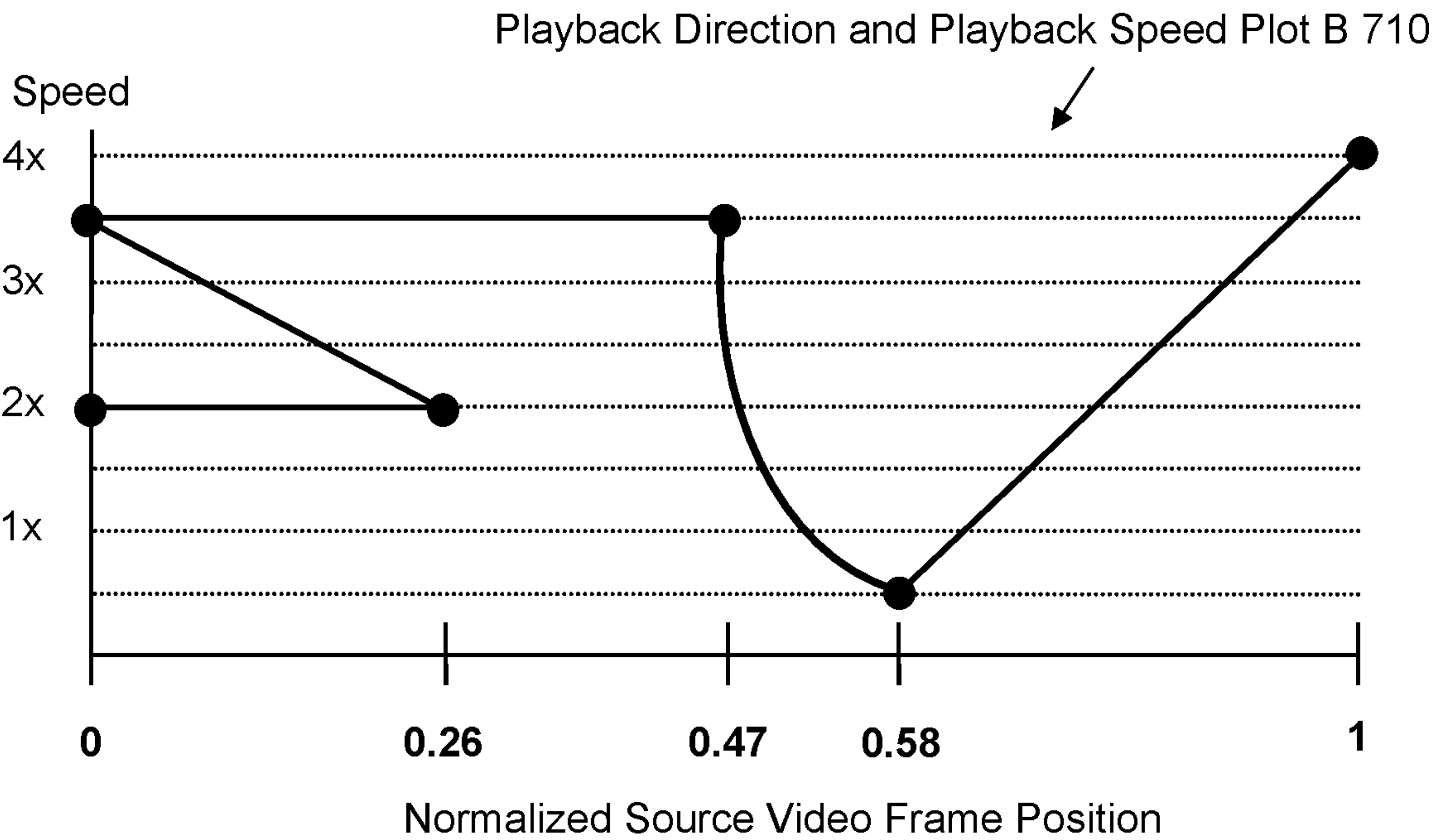


FIG. 7C

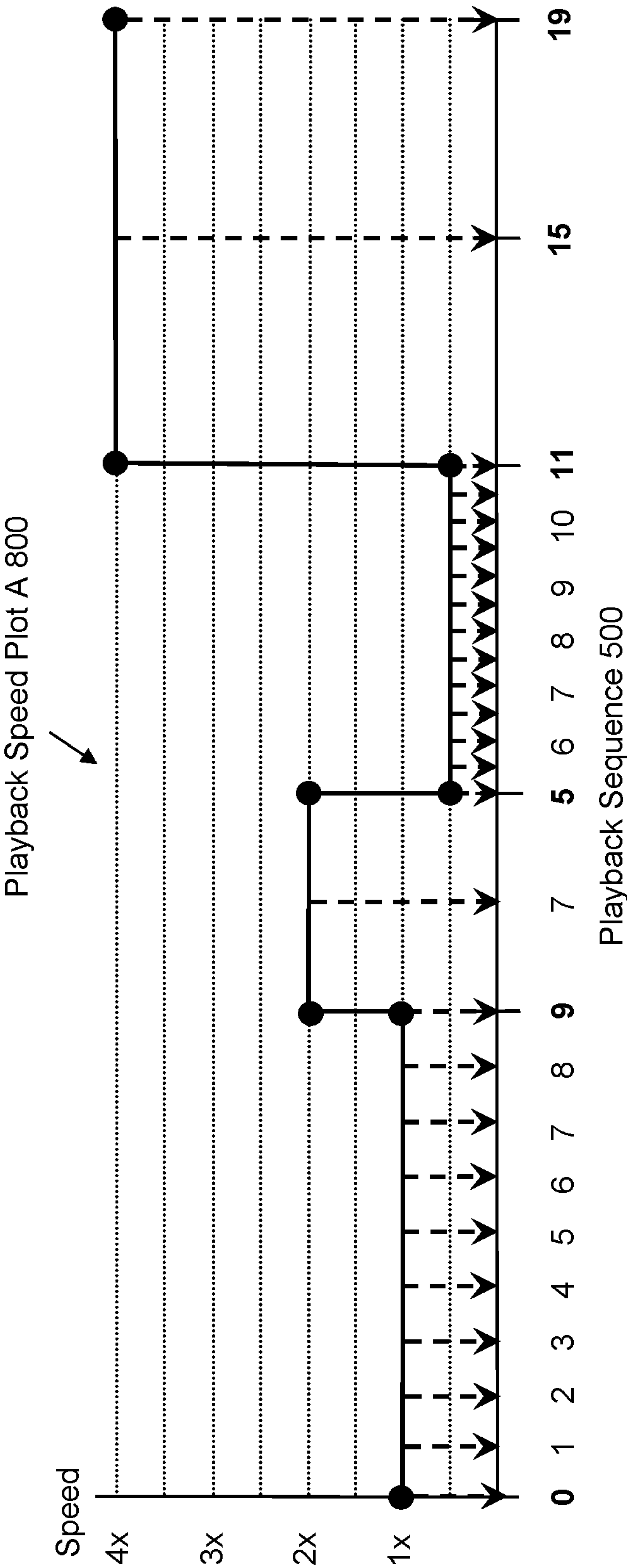


FIG. 8A

Speed Ramped Video Frames A 810



FIG. 8B

1

**SYSTEMS AND METHODS FOR
BIDIRECTIONAL SPEED RAMPING**

FIELD

This disclosure relates to facilitating user controlled bidirectional speed ramping of visual content during playback.

BACKGROUND

Video applications may allow a user to change playback speeds of a video based on playback time locations. Changing playback speeds of a video based on playback time locations may result in the video running out of playback content prior to the desired end points. For example, a user may change a playback speed of a video having a duration of five minutes. At the four minute mark, the user may set the playback speed of the video to be 4× speed for thirty seconds. At the four minute mark, the video only has fifteen seconds of playback content at 4× speed. The video will run out of playback content prior to the end of the desired thirty-second segment at 4× speed.

SUMMARY

This disclosure relates to bidirectional speed ramping. Electronic information defining visual content within video frames may be accessed. Video frames may be ordered in a source sequence. Positions in the source sequence may be associated with playback directions. Video frames may be ordered in a playback sequence based on the playback directions. The playback sequence may characterize a playback order in which video frames are displayed during playback. Video frames in the playback sequence may be associated with playback speeds. The playback speeds may determine perceived speeds with which the visual content is displayed during playback. Speed ramped video frames may be determined based on the playback sequence and the playback speeds. A speed ramped video may be generated based on the speed ramped video frames.

A system for bidirectional speed ramping may include one or more physical processors, and/or other components. The physical processor(s) may be configured by machine-readable instructions. Executing the machine-readable instructions may cause the physical processor(s) to facilitate bidirectional speed ramping. The machine-readable instructions may include one or more computer program components. The computer program components may include one or more of an access component, a playback direction component, a playback sequence component, a playback speed component, a speed ramped video frame component, a speed ramped video component, and/or other computer program components.

The access component may be configured to access electronic information and/or other information. The electronic information may be stored in a storage medium and/or in other locations. The electronic information may define visual content within video frames for playback. Visual content may refer to media content that may be observed visually. Visual content may include one or more videos stored in one or more formats/container, and/or other visual content. The video frames may be ordered in a source sequence. In some implementations, the source sequence may characterize a source order corresponding to a sequence in which the visual content occurred at capture.

The playback direction component may be configured to associate one or more positions in the source sequence with

2

one or more playback directions. The playback directions may include a forward playback direction, a reverse playback direction, and/or other directions.

The playback sequence component may be configured to order the video frames in a playback sequence. The video frames may be ordered in the playback sequence based on the playback direction(s) and/or other information. The playback sequence may characterize a playback order in which one or more of the video frames in the playback sequence may be displayed during playback. Ordering the video frames in the playback sequence may include designating one or more of the video frames in the source sequence in one or more playback positions in the playback sequence.

In some implementations, ordering the video frames in the playback sequence may include designating one of the video frames in the source sequence as a first video frame in the playback sequence and designating one of the video frames in the source sequence as a last video frame in the playback sequence. In some implementations, ordering the video frames in the playback sequence may include excluding one or more of the video frames in the source sequence from the playback sequence.

The playback speed component may be configured to associate one or more of the video frames in the playback sequence with one or more playback speeds. The playback speeds may determine one or more perceived speeds with which the visual content is displayed during playback.

The speed ramped video frame component may be configured to determine speed ramped video frames to be included in one or more speed ramped videos. The speed ramped video frames may be determined based on the playback sequence, the playback speed(s), and/or other information. In some implementations, determining the speed ramped video frames may include identifying one or more playback positions in the playback sequence based on the playback speed(s) and/or other information. The playback position(s) may correspond to the speed ramped video frames.

In some implementations, determining the speed ramped video frames may include, in response to a playback position aligning with a position of a video frame in the source sequence, using the video frame in the source sequence as the speed ramped video frame. Determining the speed ramped video frames may include, in response to a playback position not aligning with a position of a video frame in the source sequence, using two of the video frames in the source sequence to determine an interpolated video frame for the playback position. Determining the speed ramped video frames may include, in response to a playback position not aligning with a position of a video frame in the source sequence, using one of the video frames in the source sequence to determine a duplicated video frame for the playback position. Determining the speed ramped video frames may include modifying one or more of the video frames to include motion blur.

The speed ramped video component may be configured to generate one or more speed ramped videos. The speed ramped video(s) may be generated based on the speed ramped video frames and/or other information.

These and other objects, features, and characteristics of the system and/or method disclosed herein, as well as the methods of operation and functions of the related elements of structure and the combination of parts and economies of manufacture, will become more apparent upon consideration of the following description and the appended claims with reference to the accompanying drawings, all of which form

a part of this specification, wherein like reference numerals designate corresponding parts in the various figures. It is to be expressly understood, however, that the drawings are for the purpose of illustration and description only and are not intended as a definition of the limits of the invention. As used in the specification and in the claims, the singular form of “a”, “an”, and “the” include plural referents unless the context clearly dictates otherwise.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a system for bidirectional speed ramping.

FIG. 2 illustrates a method for bidirectional speed ramping.

FIG. 3 illustrates an example of a source sequence.

FIG. 4 illustrates examples of playback directions.

FIG. 5 illustrates an example of a playback sequence based on the playback directions shown in FIG. 4.

FIG. 6 illustrates an example of excluding video frames from a playback sequence.

FIG. 7A illustrates an example of a playback direction and speed plot.

FIG. 7B illustrates examples of playback speeds for a playback sequence based on the playback direction and speed plot shown in FIG. 7A.

FIG. 7C illustrates an example of a playback direction and speed plot.

FIG. 8A illustrates an example of a playback speed plot.

FIG. 8B illustrates an example of speed ramped video frames determined based on the playback speed plot shown in FIG. 8A.

DETAILED DESCRIPTION

FIG. 1 illustrates system 10 for bidirectional speed ramping. System 10 may include one or more of processor 11, storage medium 12, interface 13 (e.g., bus, wireless interface, etc.), and/or other components. Electronic information defining visual content within video frames may be accessed by processor 11. Video frames may be ordered in a source sequence. Positions in the source sequence may be associated with playback directions. Video frames may be ordered in a playback sequence based on the playback directions. The playback sequence may characterize a playback order in which video frames are displayed during playback. Video frames in the playback sequence may be associated with playback speeds. The playback speeds may determine perceived speeds with which the visual content is displayed during playback. Speed ramped video frames may be determined based on the playback sequence and the playback speeds. A speed ramped video may be generated based on the speed ramped video frames.

Storage medium 12 may include electronic storage medium that electronically stores information. Storage medium 12 may store software algorithms, information determined by processor 11, information received remotely, and/or other information that enables system 10 to function properly. For example, storage medium 12 may store information relating to visual content, video frames, source sequence, playback directions, playback sequence, playback speeds, speed ramped video frames, speed ramped video, and/or other information. System 10 may include electronic storage separate from storage medium 12. Electronic storage separate from storage medium 12 may perform one or more of the functionalities of storage medium 12 discussed above.

Processor 11 may be configured to provide information processing capabilities in system 10. As such, processor 11 may comprise one or more of a digital processor, an analog processor, a digital circuit designed to process information, a central processing unit, a graphics processing unit, a microcontroller, an analog circuit designed to process information, a state machine, and/or other mechanisms for electronically processing information. Processor 11 may be configured to execute one or more machine-readable instructions 100 to facilitate bidirectional speed ramping. Machine-readable instructions 100 may include one or more computer program components. Machine-readable instructions 100 may include one or more of access component 102, playback direction component 104, playback sequence component 106, playback speed component 108, speed ramped video frame component 110, speed ramped video component 112, and/or other computer program components.

Access component 102 may be configured to access electronic information 20 and/or other information. Electronic information 20 may be stored in storage medium 12 and/or in other locations. Electronic information 20 may define visual content within video frames for playback. Visual content may refer to media content that may be observed visually. Visual content may include one or more videos stored in one or more formats/container, and/or other visual content. A video may include a video clip captured by a video capture device, multiple video clips captured by a video capture device, and/or multiple video clips captured by separate video capture devices. A video may include multiple video clips captured at the same time and/or multiple video clips captured at different times. A video may include a video clip processed by a video application, multiple video clips processed by a video application and/or multiple video clips processed by separate video applications.

The video frames may be ordered in a source sequence. FIG. 3 illustrates an exemplary source sequence 300. Source sequence 300 may include video frames #0-19 and/or other video frames. In some implementations, the source sequence may characterize a source order corresponding to a sequence in which the visual content occurred at capture. For example, source sequence 300 may include video frames #0-19 corresponding to a capture time interval of the visual content. Video frames #0-9 may correspond to the first half of the capture time interval of the visual content and video frames #10-19 may correspond to the second half of the capture time interval of the visual content.

In some implementations, the source sequence may characterize a source order corresponding to a sequence ordered by one or more video edits. For example, the visual content may include multiple video clips arranged in a particular order by a video application. The source sequence may characterize the order in which the video frames appear in the visual content that includes the particular arrangement of the video clips.

Playback direction component 104 may be configured to associate one or more positions in the source sequence with one or more playback directions. The playback directions may include a forward playback direction, a reverse playback direction, and/or other directions. For example, FIG. 4 illustrates exemplary playback positions in source sequence 300. A position in source sequence 300 corresponding to video frame #0 may be associated with first playback direction A 310. First playback direction A 310 may include a forward playback direction. A position in source sequence 300 corresponding to video frame #9 may be associated with second playback direction A 320. Second playback direction

5

A **320** may include a reverse playback direction. A position in source sequence **300** corresponding to video frame #5 may be associated with third playback direction A **330**. Third playback direction A **330** may include a forward playback direction.

Playback sequence component **106** may be configured to order the video frames in a playback sequence. The playback sequence may characterize a playback order in which one or more of the video frames in the playback sequence may be displayed during playback. For example, a playback sequence in which video frames #1-3 appear in the order of video frame #1, video frame #3, video frame #2 may characterize the playback order in which the first video frame displayed during playback is video frame #1, the second video frame displayed during playback is video frame #3, and the third video frame displayed during playback is video frame #2.

The video frames may be ordered in the playback sequence based on the playback direction(s) and/or other information. Ordering the video frames in the playback sequence may include designating one or more of the video frames in the source sequence in one or more playback positions in the playback sequence. For example, FIG. 5 illustrates exemplary playback sequence **500**. Video frames may be ordered in playback sequence **500** based on the playback directions shown in FIG. 4. In playback sequence **500**, video frames #0-9 may appear in numerical order (based on forward playback direction of first playback direction A **310**). Playback sequence **500** may then include video frames #8-5 in reverse numerical order (based on reverse playback direction of second playback direction A **320**). Playback sequence **500** may then include video frames #6-19 in numerical order (based on forward playback direction of third playback direction A **330**).

In some implementations, ordering the video frames in the playback sequence may include designating one of the video frames in the source sequence as a first video frame in the playback sequence and designating one of the video frames in the source sequence as a last video frame in the playback sequence. For example, in FIG. 4, video frame #1 may be designated as the first video frame in playback sequence **500**. Video frame #19 may be designated as the last video frame in playback sequence **500**. In some implementations, the first video frame in the source sequence (e.g., video frame #0 in source sequence **300**) and/or the last video frame in the source sequence (e.g., video frame #19 in source sequence **300**) may be required to be the first and/or the last video frame in the playback sequence.

In some implementations, ordering the video frames in the playback sequence may include excluding one or more of the video frames in the source sequence from the playback sequence. For example, FIG. 6 illustrates exemplary exclusion of video frames from a playback sequence. In FIG. 6, playback directions may include first playback direction B **610** (forward playback direction), second playback direction B **620** (reverse playback direction), third playback direction B **630** (forward playback direction), and/or other playback direction. Video frame #2 associated with the beginning of first playback direction B **610** may be designated as first video frame **640** in the playback sequence. Video frame #16 associated with the end of third playback direction B **630** may be designated as last video frame **650** in the playback sequence. Such designation of the first and last video frames in the playback sequence may result in a first portion (e.g., video frames #0-1, etc.) and a last portion (e.g., video frames #17-19, etc.) of the visual content being excluded from the playback sequence. In

6

some implementations, one or more of the video frames excluded from the playback sequence may include one or more video frames in the middle of the source sequence. For example, in FIG. 6, one or more video frames in the middle of source sequence **300** (e.g., video frames #11-14) may be excluded from the playback sequence. The playback sequence may skip from video frame #10 to video frame #15.

Playback speed component **108** may be configured to associate one or more of the video frames in the playback sequence with one or more playback speeds. The playback speeds may determine one or more perceived speeds with which the visual content is displayed during playback. The playback speeds may allow the visual content to be displayed at a slower speed (e.g., 0.5× speed, etc.), at a default speed (e.g., 1× speed, etc.), and/or at a faster speed (e.g., 2× speed, etc.).

For example, FIG. 7A illustrates an exemplary playback direction and playback speed plot A **700**. Playback direction and playback speed plot A **700** may show a plot of playback directions and playback speeds for video frames as a function of source video frame position. Source video frame positions #0-9 may be associated with a forward playback direction and a playback speed of 1× speed. Source video frame positions #9-5 may be associated with a reverse playback direction and a playback speed of 2× speed. Source video frame positions #5-11 may be associated with a forward playback direction and a playback speed of 0.5× speed. Source video frame positions #11-19 may be associated with a forward playback direction and a playback speed of 4× speed.

The use of source video frame positions to determine playback directions and/or playback speeds of a video may allow a user/system to change the playback directions and/or the playback speeds of the video without the video running out of playback content prior to the desired end points. The use of source video frame positions to determine playback directions and/or the playback speeds of a video may allow a user/system to copy, cut, paste, and/or otherwise move a portion of the video without affecting the playback directions and/or the playback speeds of the portion of the video.

FIG. 7B illustrates exemplary playback speeds for playback sequence **500**. Playback speeds for playback sequence **500** may be based on the playback directions and playback speeds shown in playback direction and playback speed plot A **700**. In FIG. 7B, video frames #0-8 of playback sequence **500** may be associated with 1× speed. Video frames #9-6 may be associated with 2× speed. Video frames #5-10 may be associated with 0.5× speed. Video frames #11-18 may be associated with 4× playback speed.

Although speed values in playback direction and playback speed plot A **700** are shown to not vary between ranges of source video frame positions in the same playback direction (e.g., between positions #0-9, #9-5, #5-11, #11-19), this is merely for ease of reference and is not limiting. For example, playback speeds associated with video frames may change linearly and/or non-linearly. For example, playback speeds associated with video frames may include an increasing slope and/or a decreasing slope. Although speed values and playback directions in playback direction and playback speed plot A **700** are shown to change at whole number source video frame positions, this is merely for ease of reference and is not limiting. Speed values and/or playback directions may change at one or more non-whole number source video frame positions.

For example, FIG. 7C illustrates an exemplary playback direction and playback speed plot B **710** with sloping

speeds. In some implementations, source video frame positions may be normalized to a value of 1 and/or other values. For example, in FIG. 7C, the source video frame position may be normalized to a value of 1. For example, source video frame positions of #0, 5, 9, 11, and 19 in FIG. 7A may correspond to normalized source video frame positions of #0, 0.26, 0.47, 0.58, and 1.

In FIG. 7C, normalized source video frame positions #0-0.26 may be associated with a forward playback direction and a playback speed of 2× speed. Normalized source video frame positions #0.26-0 may be associated with a reverse playback direction and playback speeds that linearly increases from 2× speed to 3.5× speed. Normalized source video frame positions #0-0.47 may be associated with a forward playback direction and a playback speed of 3.5× speed. Normalized source video frame positions #0.47-0.58 may be associated with a forward playback direction and playback speeds that non-linearly decreases from 3.5× speed to 0.5× speed. Normalized source video frame positions #0.58-1 may be associated with a forward playback direction and playback speeds that linearly increases from 0.5× speed to 4× speed. Other changes in playback directions and playback speeds, and other positions of change in the source video frame positions are contemplated.

Speed ramped video frame component 110 may be configured to determine speed ramped video frames to be included in one or more speed ramped videos. The speed ramped video frames may be determined based on the playback sequence, the playback speed(s), and/or other information. Determining the speed ramped video frames may include identifying one or more playback positions in the playback sequence based on the playback speed(s) and/or other information. The playback position(s) may correspond to the speed ramped video frames. For example, speed ramped video frame component 110 may identify one or more playback positions in the playback sequence based on the playback speeds. From these playback positions, speed ramped video frame component 110 may select and/or generate one or more video frames to be included as speed ramped video frames. This may allow rendering of a new set of video frames that capture the ordering of video frames based on the playback sequence and the timing of the video frames based on the playback speeds.

For example, FIG. 8A illustrates an exemplary playback speed plot A 800. Playback speed plot A 800 may show a plot of playback speeds for video frames as a function of playback sequence 500. Speeds shown in FIG. 8A for different portions of playback sequence 500 may correspond to the speeds shown in FIGS. 7A-7B. Speed ramped video frame component 110 may identify one or more playback positions (shown in FIG. 8A as dashed arrows) in playback sequence 500 based on the playback speeds.

For example, between video frames #0-9 of playback sequence 500, one playback position may be identified for every video frame. Playback positions identified may include playback positions #0, #1, #2, #3, #4, #5, #6, #7, #8, and #9. Identifying one playback position per video frame may correspond to a playback speed of 1×.

Between video frames #9-5 of playback sequence 500, one playback position may be identified for every two video frames. Playback positions identified may include playback positions #7 and #5. Identifying one playback position per two video frames may correspond to a playback speed of 2×.

Between video frames #5-11 of playback sequence 500, two playback positions may be identified for every video frame. Playback positions identified may include playback positions #5.5, #6, #6.5, #7, #7.5, #8, #8.5, #9, #9.5, #10,

#10.5, and #11. Identifying two playback positions per video frame may correspond to a playback speed of 0.5×.

Between video frames #11-19 of playback sequence 500, one playback position may be identified for every four video frames. Playback positions identified may include playback positions #15 and #19. Identifying one playback position per four video frames may correspond to a playback speed of 4×.

FIG. 8B illustrates exemplary speed ramped video frames A 810. Speed ramped video frames A 810 may include video frames corresponding to the positions identified in FIG. 8A. Speed ramped video frames A 810 may include video frames corresponding to playback positions #0, #1, #2, #3, #4, #5, #6, #7, #8, and #9 (corresponding to playback speed of 1×); #7 and #5 (corresponding to playback speed of 2×); #5.5, #6, #6.5, #7, #7.5, #8, #8.5, #9, #9.5, #10, #10.5, and #11 (corresponding to playback speed of 0.5×); and #15 and #19 (corresponding to playback speed of 4×).

Playback positions identified by speed ramped video frame component 110 may or may not correspond to positions of video frames in the source sequence. In some implementations, determining the speed ramped video frames may include, in response to a playback position aligning with a position of a video frame in the source sequence, using the video frame in the source sequence as the speed ramped video frame. For example, in FIG. 8A, the following playback positions of playback sequence 500 may align with video frames in the source sequence: #0, #1, #2, #3, #4, #5, #6, #7, #8, #9, #7, #5, #6, #7, #8, #9, #10, #11, #15, and #19. For these playback positions, speed ramped video frame component 110 may select the corresponding video frames in the source sequence as the speed ramped video frames (e.g., selecting video frame #9 in source sequence 300 for playback position #9, etc.).

In some implementations, determining the speed ramped video frames may include, in response to a playback position not aligning with a position of a video frame in the source sequence, using multiple video frames in the source sequence to determine an interpolated video frame for the playback position. For example, for playback position #5.5, a speed ramped video frame may be interpolated using video frame #5 and video frame #6 in source sequence 300. In some implementations, one or more images may be given more weight than other images for video frame interpolation. For example, an identified playback position may include playback position #5.3. A speed ramped video frame generated for playback position #5.3 may include interpolation of video frame #5 and video frame #6 in the source sequence, where video frame #5 is given more influence over the interpolation. This may allow the interpolated video frame for playback position #5.3 to appear closer to video frame #5 than video frame #6.

In some implementations, determining the speed ramped video frames may include, in response to a playback position not aligning with a position of a video frame in the source sequence, using one of the video frames in the source sequence to determine a duplicated video frame for the playback position. For example, for playback position #6.5, a speed ramped video frame may be duplicated from video frame #6 in source sequence 300. Duplication of video frames may allow one or more video frames in source sequence 300 to appear multiple times in a row and simulate a slower playback speed. In some implementations, the speed ramped video frames may include interpolated video frames and duplicated video frames.

In some implementations, determining the speed ramped video frames may include modifying one or more of the

video frames to include motion blur. Motion blur may emphasize the perceived increase in speed of playback for the visual content. For example, in FIG. 8B, speed ramped video frames corresponding to the sped-up portions of the visual content (e.g., video frames #7 and #5 corresponding to playback speed of 2×, video frames #15 and #19 corresponding to playback speed of 4×, etc.) may be modified to include motion blur. The amount of motion blur may depend on the amount of playback speed increase, with greater playback speeds corresponding to greater amounts of motion blur.

Speed ramped video component **112** may be configured to generate one or more speed ramped videos. The speed ramped video(s) may be generated based on the speed ramped video frames and/or other information. For example, speed ramped video component **112** may encode the speed ramped video frames into a new video file. The speed ramped video frames may be encoded using one or more encoding framerates (e.g., 30 frames per second, variable framerate, etc.).

While the present disclosure may be directed to videos, one or more other implementations of the system may be configured for other types media content. Other types of media content may include one or more of audio content (e.g., music, podcasts, audio books, and/or other audio content), multimedia presentations, photos, slideshows, and/or other media content.

Although processor **11** and storage medium **12** are shown to be connected to an interface **13** in FIG. 1, any communication medium may be used to facilitate interaction between any components of system **10**. One or more components of system **10** may communicate with each other through hard-wired communication, wireless communication, or both. For example, one or more components of system **10** may communicate with each other through a network. For example, processor **11** may wirelessly communicate with storage medium **12**. By way of non-limiting example, wireless communication may include one or more of radio communication, Bluetooth communication, Wi-Fi communication, cellular communication, infrared communication, or other wireless communication. Other types of communications are contemplated by the present disclosure.

Although processor **11** is shown in FIG. 1 as a single entity, this is for illustrative purposes only. In some implementations, processor **11** may comprise a plurality of processing units. These processing units may be physically located within the same device, or processor **11** may represent processing functionality of a plurality of devices operating in coordination. Processor **11** may be configured to execute one or more components by software; hardware; firmware; some combination of software, hardware, and/or firmware; and/or other mechanisms for configuring processing capabilities on processor **11**.

It should be appreciated that although computer components **102**, **104**, **106**, **108**, **110**, and **112** are illustrated in FIG. 1 as being co-located within a single processing unit, in implementations in which processor **11** comprises multiple processing units, one or more of computer program components **102**, **104**, **106**, **108**, **110**, and/or **112** may be located remotely from the other computer program components.

The description of the functionality provided by the different computer program components described herein is for illustrative purposes, and is not intended to be limiting, as any of computer program components may provide more or less functionality than is described. For example, one or more of computer program components **102**, **104**, **106**, **108**, **110**, and/or **112** may be eliminated, and some or all of its

functionality may be provided by other computer program components. As another example, processor **11** may be configured to execute one or more additional computer program components that may perform some or all of the functionality attributed to one or more of computer program components **102**, **104**, **106**, **108**, **110**, and/or **112** described herein.

The electronic storage media of storage medium **12** may be provided integrally (i.e., substantially non-removable) with one or more components of system **10** and/or removable storage that is connectable to one or more components of system **10** via, for example, a port (e.g., a USB port, a Firewire port, etc.) or a drive (e.g., a disk drive, etc.). Storage medium **12** may include one or more of optically readable storage media (e.g., optical disks, etc.), magnetically readable storage media (e.g., magnetic tape, magnetic hard drive, floppy drive, etc.), electrical charge-based storage media (e.g., EPROM, EEPROM, RAM, etc.), solid-state storage media (e.g., flash drive, etc.), and/or other electronically readable storage media. Storage medium **12** may be a separate component within system **10**, or storage medium **12** may be provided integrally with one or more other components of system **10** (e.g., processor **11**). Although storage medium **12** is shown in FIG. 1 as a single entity, this is for illustrative purposes only. In some implementations, storage medium **12** may comprise a plurality of storage units. These storage units may be physically located within the same device, or storage medium **12** may represent storage functionality of a plurality of devices operating in coordination.

FIG. 2 illustrates method **200** for bidirectional speed ramping. The operations of method **200** presented below are intended to be illustrative. In some implementations, method **200** may be accomplished with one or more additional operations not described, and/or without one or more of the operations discussed. In some implementations, two or more of the operations may occur substantially simultaneously.

In some implementations, method **200** may be implemented in one or more processing devices (e.g., a digital processor, an analog processor, a digital circuit designed to process information, a central processing unit, a graphics processing unit, a microcontroller, an analog circuit designed to process information, a state machine, and/or other mechanisms for electronically processing information). The one or more processing devices may include one or more devices executing some or all of the operations of method **200** in response to instructions stored electronically on one or more electronic storage mediums. The one or more processing devices may include one or more devices configured through hardware, firmware, and/or software to be specifically designed for execution of one or more of the operations of method **200**.

Referring to FIG. 2 and method **200**, at operation **201**, electronic information may be accessed. The electronic information may be stored in a storage medium and/or other locations. The electronic information may define visual content within video frames for playback. The video frames may be ordered in a source sequence. In some implementations, operation **201** may be performed by a processor component the same as or similar to access component **102** (shown in FIG. 1 and described herein).

At operation **202**, one or more positions in the source sequence may be associated with one or more playback directions. The playback directions may include a forward playback direction and a reverse playback direction. In some implementations, operation **202** may be performed by a

11

processor component the same as or similar to playback direction component **104** (shown in FIG. 1 and described herein).

At operation **203**, the video frames may be ordered in a playback sequence based on the one or more playback directions. The playback sequence may characterize a playback order in which one or more of the video frames in the playback sequence are displayed during playback. In some implementations, operation **203** may be performed by a processor component the same as or similar to playback sequence component **106** (shown in FIG. 1 and described herein).

At operation **204**, one or more of the video frames in the playback sequence may be associated with one or more playback speeds. The one or more playback speeds may determine one or more perceived speeds with which the visual content is displayed during playback. In some implementations, operation **204** may be performed by a processor component the same as or similar to playback speed component **108** (shown in FIG. 1 and described herein).

At operation **205**, speed ramped video frames to be included in a speed ramped video may be determined. The speed ramped video frames may be determined based on the playback sequence and the one or more playback speeds. In some implementations, operation **205** may be performed by a processor component the same as or similar to speed ramped video frame component **110** (shown in FIG. 1 and described herein).

At operation **206**, the speed ramped video may be generated. The speed ramped video may be generated based on the speed ramped video frames. In some implementations, operation **206** may be performed by a processor component the same as or similar to speed ramped video component **112** (shown in FIG. 1 and described herein).

Although the system(s) and/or method(s) of this disclosure have been described in detail for the purpose of illustration based on what is currently considered to be the most practical and preferred implementations, it is to be understood that such detail is solely for that purpose and that the disclosure is not limited to the disclosed implementations, but, on the contrary, is intended to cover modifications and equivalent arrangements that are within the spirit and scope of the appended claims. For example, it is to be understood that the present disclosure contemplates that, to the extent possible, one or more features of any implementation can be combined with one or more features of any other implementation.

What is claimed is:

1. A system for bidirectional frame ordering, the system comprising:

one or more physical processors configured by machine-readable instructions to:

access electronic information stored in a storage medium, the electronic information defining visual content within video frames of a video for playback, the video frames ordered in a source sequence;

associate one or more positions in the source sequence with one or more playback directions based on a user setting the one or more playback directions, the playback directions including a forward playback direction and a reverse playback direction, wherein associating the one or more positions in the source sequence with the one or more playback directions includes associating a first position in the source sequence with the reverse playback direction based on the user setting the reverse playback direction for the first position in the source sequence and associ-

12

ating a second position in the source sequence with the forward playback direction based on the user setting the forward playback direction for the second position in the source sequence, the second position preceding the first position in the source sequence; order the video frames in a playback sequence based on the one or more playback directions, the playback sequence characterizing a playback order in which one or more of the video frames in the playback sequence are displayed during playback, wherein ordering of the video frames in the playback sequence based on the reverse playback direction for the first position in the source sequence and the forward playback direction for the second position in the source sequence results in the playback sequence including the video frames between the first position and the second position in the source sequence ordered in reverse order followed by the video frames from the second position ordered in forward order; and

generate a new video based on the ordering of the video frames in the playback sequence, the new video generated to include the video frames within the playback sequence, the video frames ordered within the new video in accordance with the ordering of the video frames in the playback sequence.

2. The system of claim 1, wherein the source sequence characterizes a source order corresponding to a sequence in which the visual content occurred at capture.

3. The system of claim 1, wherein ordering the video frames in the playback sequence includes designating one of the video frames in the source sequence as a first video frame in the playback sequence and designating one of the video frames in the source sequence as a last video frame in the playback sequence.

4. The system of claim 1, wherein ordering the video frames in the playback sequence includes excluding one or more of the video frames in the source sequence from the playback sequence.

5. The system of claim 1, wherein ordering the video frames in the playback sequence includes designating one or more of the video frames in the source sequence in one or more playback positions in the playback sequence.

6. The system of claim 1, wherein the new video is generated further based on one or more playback speeds for one or more of the video frames in the playback sequence.

7. The system of claim 6, wherein one or more playback positions in the playback sequence are identified for inclusion in the new video based on the one or more playback speeds.

8. The system of claim 6, wherein the new video includes an interpolated video frame, the interpolated video frame determined based on at least two of the video frames.

9. The system of claim 1, wherein one or more of the video frames are modified to include motion blur.

10. A method for bidirectional frame ordering, the method performed by a computing system including one or more processors, the method comprising:

accessing, by the computing system, electronic information stored in a storage medium, the electronic information defining visual content within video frames of a video for playback, the video frames ordered in a source sequence;

associating, by the computing system, one or more positions in the source sequence with one or more playback directions based on a user setting the one or more playback directions, the playback directions including

13

a forward playback direction and a reverse playback direction, wherein associating the one or more positions in the source sequence with the one or more playback directions includes associating a first position in the source sequence with the reverse playback direction based on the user setting the reverse playback direction for the first position in the source sequence and associating a second position in the source sequence with the forward playback direction based on the user setting the forward playback direction for the second position in the source sequence, the second position preceding the first position in the source sequence;

ordering, by the computing system, the video frames in a playback sequence based on the one or more playback directions, the playback sequence characterizing a playback order in which one or more of the video frames in the playback sequence are displayed during playback, wherein ordering of the video frames in the playback sequence based on the reverse playback direction for the first position in the source sequence and the forward playback direction for the second position in the source sequence results in the playback sequence including the video frames between the first position and the second position in the source sequence ordered in reverse order followed by the video frames from the second position ordered in forward order; and

generating, by the computing system, a new video based on the ordering of the video frames in the playback sequence, the new video generated to include the video frames within the playback sequence, the video frames ordered within the new video in accordance with the ordering of the video frames in the playback sequence.

11. The method of claim 10, wherein the source sequence characterizes a source order corresponding to a sequence in which the visual content occurred at capture.

12. The method of claim 10, wherein ordering the video frames in the playback sequence includes designating one of the video frames in the source sequence as a first video frame in the playback sequence and designating one of the video frames in the source sequence as a last video frame in the playback sequence.

13. The method of claim 10, wherein ordering the video frames in the playback sequence includes excluding one or more of the video frames in the source sequence from the playback sequence.

14. The method of claim 10, wherein ordering the video frames in the playback sequence includes designating one or more of the video frames in the source sequence in one or more playback positions in the playback sequence.

15. The method of claim 10, wherein the new video is generated further based on one or more playback speeds for one or more of the video frames in the playback sequence.

16. The method of claim 15, wherein one or more playback positions in the playback sequence are identified for inclusion in the new video based on the one or more playback speeds.

14

17. The method of claim 15, wherein the new video includes an interpolated video frame, the interpolated video frame determined based on at least two of the video frames.

18. The method of claim 10, wherein one or more of the video frames are modified to include motion blur.

19. A system for bidirectional frame ordering, the system comprising:
 one or more physical processors configured by machine-readable instructions to:
 access electronic information stored in a storage medium, the electronic information defining visual content within video frames of a video for playback, the video frames ordered in a source sequence;
 associate one or more positions in the source sequence with one or more playback directions based on a user setting the one or more playback directions, the playback directions including a forward playback direction and a reverse playback direction, wherein associating the one or more positions in the source sequence with the one or more playback directions includes associating a first position in the source sequence with the reverse playback direction based on the user setting the reverse playback direction for the first position in the source sequence and associating a second position in the source sequence with the forward playback direction based on the user setting the forward playback direction for the second position in the source sequence, the second position preceding the first position in the source sequence;
 order the video frames in a playback sequence based on the one or more playback directions, the playback sequence characterizing a playback order in which one or more of the video frames in the playback sequence are displayed during playback, wherein ordering of the video frames in the playback sequence based on the reverse playback direction for the first position in the source sequence and the forward playback direction for the second position in the source sequence results in the playback sequence including the video frames between the first position and the second position in the source sequence ordered in reverse order followed by the video frames from the second position ordered in forward order, further wherein ordering the video frames in the playback sequence includes designating one of the video frames in the source sequence as a first video frame in the playback sequence and designating one of the video frames in the source sequence as a last video frame in the playback sequence; and
 generate a new video based on the ordering of the video frames in the playback sequence, the new video generated to include the video frames within the playback sequence, the video frames ordered within the new video in accordance with the ordering of the video frames in the playback sequence.

20. The system of claim 19, wherein the new video is generated further based on one or more playback speeds for one or more of the video frames in the playback sequence.

* * * * *